Efficiency calibration of the neutron detector BELEN-48 with (p,n) and (α,n) reactions at the PTB Braunschweig *

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The BEta-deLayEd Neutron detector BELEN is a highly efficient device designed for the DESPEC project at FAIR. It has already been successfully used during the experiments S323 and S410 at the Fragment Separator to measure β-delayed neutron probabilities and half-lives of neutron-rich nuclei close to the r-process path, for nuclear structure and nuclear astrophysics studies.

In its present version, it consists of 48 ^{3}He proportional counters arranged to form three concentric rings embedded in a polyethylene matrix. Due to the thermalization process, the information about the initial neutron energy is lost but the detection efficiency is strongly increased. Therefore the position and number of counters in the rings are designed in such a way that the efficiency remains constant over a broad range of neutron energy from thermal up to a few MeV. The simulations are performed with an MCNPX code and have to be validated by experiments that make use of known neutron fluxes produced in the center of the detector.

Measurements with a calibrated ^{252}Cf source provide only one efficiency value corresponding to a spectrum-averaged neutron energy of 2.14 MeV. In order to have a more stringent test on the simulated efficiency curve, the calibration has been extended with well-known (p,n) and (α,n) reactions on ^{13}C and ^{51}V targets producing neutrons with limited energy spread, ranging between 0.2 and 5.3 MeV. The list of reactions and energies used is summarized in table 1.

Reaction	E_{proj} [MeV]	E_{n} [MeV] min	max
^{51}V(p,n)^{51}Cr	1.80	0.20	0.25
^{51}V(p,n)^{51}Cr	2.14	0.51	0.59
^{51}V(p,n)^{51}Cr	2.27	0.63	0.73
^{13}C(p,n)^{13}N	4.45	0.77	1.36
^{13}C(α,n)^{16}O	1.05	2.5	3.2
^{13}C(α,n)^{16}O	3.30	3.6	5.3

Table 1: List of reactions used for the calibration. Maximum and minimum neutron energies E_{n} refer to the smaller (forward) and largest (backward) angle covered by BELEN-48, i.e. from about 16 to 164 degrees.

The experiment was performed at the PTB ion accelerator facility (PIAF) of the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig/Germany, where a Van de Graaff accelerator and cyclotron provided the α and p beams of desired energy and intensity. The BELEN-48 polyethylene matrix was installed with the air-cooled target holder located at the end of a beam line at the center of the detector. The target chamber was designed as a Faraday cup to measure the beam currents on target with suppression electrodes and collimators. At a second beam line it was possible to produce the same neutron flux as inside BELEN, with very similar target and beam conditions, and to measure reaction yields and angular distributions with the calibrated neutron detectors of PTB at several angles with respect to the beam axis. The reactions on ^{13}C target show large anisotropy in the center-of-mass frame. The angular distributions of ^{51}V(p,n)^{51}Cr are still to be measured.

The measured angular distributions need to be taken into account in the simulation of the efficiency for each reaction and beam energy, since neutrons enter BELEN with different probabilities and energies at different angles. For the moment the preliminary experimental efficiency (Fig. 1) is obtained as the ratio of neutrons *detected* in BELEN-48, and a normalized-to-isotropy value for neutrons *emitted*. The normalization takes into account each measured angular distribution and the detection solid angle, making a comparison of all data and simulation possible.

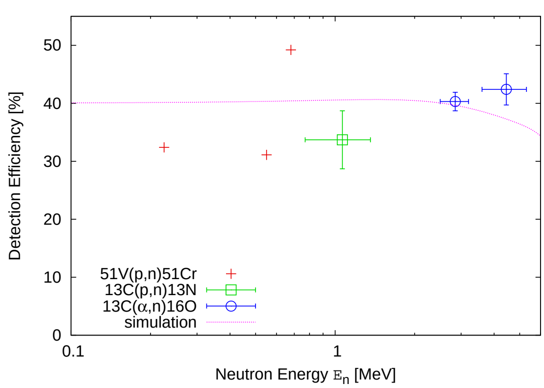

Figure 1: Comparison of the efficiency curve simulated with MCNPX (dotted line) and preliminary experimental values. The Vanadium data is shown without uncertainty due to the missing angular distribution information that prevents its normalization.

* This work was supported by the Helmholtz association via the Young Investigators Group VH-NG-627.